PATENT

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Buazza et al.

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PRELIMINARY AMENDMENT

Commissioner for Patents
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Amendment

Sir:

Please amend the above-captioned application as follows:

In the Specification:

Before the text on page 1, please add the following paragraph:

PRIORITY CLAIM

-- This application is a divisional of U.S. Patent Application Serial No. 09/272,815 filed on March 19, 1999.--

A clean version of this paragraph has been included as an amendment sheet.

In the Claims:

Please cancel claims 1-345 and 400-442.

It is believed that no fees are due in connection with the filing of this Preliminary Amendment. However, if any fees are due, the Assistant Commissioner is hereby authorized to deduct said fees from Conley, Rose & Tayon Deposit Account No. 50-1505/5040-04203/EBM.

Respectfully submitted,

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PRIORITY CLAIM

This application is a divisional of U.S. Patent Application Serial No. 09/272,815 filed on March 19, 1999.

process. For example, due to the relatively rapid nature of ultraviolet light initiated reactions, it is a challenge to provide a composition that is ultraviolet light curable to form an eyeglass lens. Excessive exothermic heat tends to cause defects in the cured lens. To avoid such defects, the level of photoinitiator may be reduced to levels below what is customarily employed in the ultraviolet curing art.

While reducing the level of photoinitiator addresses some problems, it may also cause others. For instance, lowered levels of photoinitiator may cause the material in regions near an edge of the lens and proximate a gasket wall in a mold cavity to incompletely cure due to the presence of oxygen in these regions (oxygen is believed to inhibit curing of many lens forming compositions or materials). Uncured lens forming composition tends to result in lenses with "wet" edges covered by sticky uncured lens forming composition. Furthermore, uncured lens forming composition may migrate to and contaminate the optical surfaces of the lens upon demolding. The contaminated lens is then often unusable.

Uncured lens forming composition has been addressed by a variety of methods (see, e.g., the methods described in U.S. Patent No. 5,529,728 to Buazza et al). Such methods may include removing the gasket and applying either an oxygen barrier or a photoinitiator enriched liquid to the exposed edge of the lens, and then re-irradiating the lens with a dosage of ultraviolet light sufficient to completely dry the edge of the lens prior to demolding. During such irradiation, however, higher than desirable levels of irradiation, or longer than desirable periods of irradiation, may be required. The additional ultraviolet irradiation may in some circumstances cause defects such as yellowing in the lens.

The low photoinitiator levels utilized in many ultraviolet curable lens forming compositions may produce a lens that, while fully-cured as measured by percentage of remaining double bonds, may not possess sufficient cross-link density on the lens surface

to provide desirable dye absorption characteristics during the tinting process.

Various methods of increasing the surface density of such ultraviolet light curable lenses are described in U.S. Patent No. 5,529,728 to Buazza et al. In one method, the lens is demolded and then the surfaces of the lens are exposed directly to ultraviolet light. The relatively short wavelengths (around 254 nm) provided by some ultraviolet light sources (e.g., a mercury vapor lamp) tend to cause the material to cross-link quite rapidly. An undesirable effect of this method, however, is that the lens tends to yellow as a result of such exposure. Further, any contaminants on the surface of the lens that are exposed to short wavelengths of high intensity ultraviolet light may cause tint defects.

Another method involves exposing the lens to relatively high intensity ultraviolet radiation while it is still within a mold cavity formed between glass molds. The glass molds tend to absorb the more effective short wavelengths, while transmitting wavelengths of about 365 nm. This method generally requires long exposure times and often the infrared radiation absorbed by the lens mold assembly will cause premature release of the lens from a mold member. The lens mold assembly may be heated prior to exposure to high intensity ultraviolet light, thereby reducing the amount of radiation necessary to attain a desired level of cross-link density. This method, however, is also associated with a higher rate of premature release.

It is well known in the art that a lens mold/gasket assembly may be heated to cure the lens forming composition from a liquid monomer to a solid polymer. It is also well known that such a lens may be thermally postcured by applying convective heat to the lens after the molds and gaskets have been removed from the lens.

In this application the terms "lens forming material" and "lens forming compositions" are used interchangeably.

SUMMARY OF THE INVENTION

An embodiment of an apparatus for preparing an eyeglass lens is described. The apparatus includes a coating unit and a lens curing unit. The coating unit may be configured to coat either mold members or lenses. Preferably, the coating unit is a spin coating unit. The lens curing unit may be configured to direct activating light toward mold members. The mold members are part of a mold assembly that may be placed within the lens curing unit. Depending on the type of lens forming composition used, the apparatus may be used to form photochromic and non-photochromic lenses. The apparatus is preferably configured to allow the operation of both the coating unit and the lens curing unit substantially simultaneously.

The coating unit is preferably a spin coating unit. The spin coating unit preferably comprises a holder for holding an eyeglass lens or a mold member. The holder is preferably coupled to a motor that is preferably configured to rotate the holder. An activating light source may be incorporated into a cover. The cover may be drawn over the body of the lens curing unit, covering the coating units. The activating light source is preferably positioned, when the cover is closed, such that activating light may be applied to the mold member or lens positioned within the coating unit. An activating light source may be an ultraviolet light source, an actinic light source (e.g., a light source producing light having a wavelength between about 380 nm to 490 nm), a visible light source and/or an infra-red light source. Preferably, the activating light source is an ultraviolet light source.

The lens curing unit includes at least one, preferably two activating light sources for irradiating a mold assembly. Mold assembly holders may be positionable within the lens forming apparatus such that the activating light may be applied to the mold member during use. A filter is preferably positioned between the mold assemblies and the activating light source. The filter is preferably configured to manipulate the intensity of

activating light that is directed toward the mold members. The filter may be a hazy filter that includes a frosted glass member. Alternatively, the filter may be a liquid crystal display ("LCD") panel.

An LCD panel for use as a filter is preferably a monochrome trans-flective panel with the back light and reflector removed. The intensity of the light is preferably reduced as the light passes through the LCD panel. The LCD panel is preferably programmable such that the light transmissibility of the LCD panel may be altered. In use, a predetermined pattern of light and dark regions may be displayed on the LCD panel to alter the intensity of light passing through the panel. One advantage of an LCD panel filter is that a pattern may be altered during a curing cycle. For example, the pattern of light and dark regions may be manipulated such that a lens is initially cured from the center of the lens, then the curing may be gradually expanded to the outer edges of the lens. This type of curing pattern may allow a more uniformly cured lens to be formed.

Another advantage is that the LCD panel may be used as a partial shutter to reduce the intensity of light reaching the mold assembly. By blackening the entire LCD panel the amount of light reaching any portion of the mold assembly may be reduced. In this manner, the LCD may be used to create "pulses" of light by alternating between a transmissive and darkened mode.

In another embodiment, an LCD panel may be used to allow different patterns and/or intensities of light to reach two separate mold assemblies. If the mold assemblies are being used to create lenses having significantly different powers, each mold assembly may require a significantly different light irradiation pattern and/or intensity. The use of an LCD filter may allow the irradiation of each of the mold assemblies to be controlled individually.

When non-LCD type filters are used, it may be necessary to maintain a library of

filters for use in the production of different types of prescription lenses. Typically, each individual prescription will need a particular filter pattern to obtain a high quality lens. Since an LCD panel is programmable in a variety of patterns, it is believed that one may use a single LCD panel, rather than a library of filters. The LCD panel may be programmed to fit the needs of the specific type of lens being formed.

The LCD panel filters may be coupled to a programmable logic device that may be used to design and store patterns for use during curing. Fig. 7–10 show a number of patterns that may be generated on an LCD panel and used to filter activating light. Each of these patterns is preferably used for the production of a lens having a specific prescription power.

The lens forming apparatus may include a post-cure unit. The post-cure unit is preferably configured to apply heat and activating light to mold assemblies or lenses disposed within the post-cure unit.

The lens forming apparatus may also include a programmable controller configured to substantially simultaneously control the operation of the coating unit, the lens curing unit and the post-cure unit. The apparatus may include a number of light probes and temperature probes disposed within the coating unit, lens curing unit, and the post-cure unit. These probes preferably relay information about the operation of the individual units to the controller. The information relayed may be used to control the operation of the individual units. The operation of each of the units may also be controlled based on the prescription of the lens being formed.

The controller may be configured to control various operations of the coating unit. For example, when a spin coating unit is used the controller may control the rotation of the lens or mold member during a coating process (e.g., whether the lens or mold

members are rotated or not and/or the speed of rotation) and the operation of the coating unit lamps (e.g., whether the lamps are on or off and/or the time the lamps are on).

The controller may also be configured to control the various operations of the lens curing unit. Some of the operations that may be controlled or measured by the controller include: (i) measuring the ambient room temperature; (ii) determining the dose of light (or initial dose of light in pulsed curing applications) required to cure the lens forming composition, based on the ambient room temperature; (iii) applying the activating light with an intensity and duration sufficient to equal the determined dose; (iv) measuring the composition's temperature response during and subsequent to the application of the dose of light; (v) calculating the dose required for the next application of activating light (in pulsed curing applications); (vi) applying the activating light with an intensity and duration sufficient to equal the determined second dose; (vii) determining when the curing process is complete by monitoring the temperature response of the lens forming composition during the application of activating light; (viii) turning the upper and lower light sources on and off independently; (ix) monitoring the lamp temperature, and controlling the temperature of the lamps by activating cooling fans proximate the lamps; and (x) turning the fans on/off or controlling the flow rate of an air stream produced by a fan to control the composition temperature;

The controller may also be configured to control the operation of the post-cure unit. Some of the operations that may be controlled include control of the operation of the lamps (e.g., whether the lamps are on or off and the time the lamps are on); and operation of the heating device (e.g., whether the heating unit is turned on or off and/or the amount of heat produced by the heating device).

Additionally, the controller provides system diagnostics and information to the operator of the apparatus. The controller may notify the user when routine maintenance is due or when a system error is detected. The controller may also manage an interlock

system for safety and energy conservation purposes. The controller may prevent the lamps from operating when the operator may be exposed to light from the lamps.

The controller may also be configured to interact with the operator. The controller preferably includes an input device and a display screen. A number of operations controlled by the controller, as described above, may be dependent on the input of the operator. The controller may prepare a sequence of instructions based on the type of lens (clear, ultraviolet/visible light absorbing, photochromic, colored, etc.), prescription, and type of coatings (e.g., scratch resistant, adhesion promoting, or tint) inputted by an operator.

A variety of lens forming compositions may be cured to form a plastic eyeglass lens in the above described apparatus. Colored lenses, photochromic lenses, and ultraviolet/visible light absorbing colorless lenses may be formed. The lens forming compositions may be formulated such that the conditions for forming the lens (e.g., curing conditions and post cure conditions) may be similar without regard to the lens being formed. In an embodiment, a clear lens may be formed under similar conditions used to form photochromic lenses by adding a colorless, non-photochromic ultraviolet/visible light absorbing compound to the lens forming composition. The curing process for forming a photochromic lens is such that higher doses of activating light than are typically used for the formation of a clear, non-ultraviolet/visible light absorbing lens may be required. In an embodiment, ultraviolet/visible light absorbing compounds may be added to a lens forming composition to produce a substantially clear lens under the more intense dosing requirements used to form photochromic lenses. The ultraviolet/visible light absorbing compounds may take the place of the photochromic compounds, making curing at higher doses possible for clear lenses. An advantage of adding the ultraviolet/visible light absorbers to the lens forming composition is that the clear lens formed may offer better protection against ultraviolet/visible light rays than a clear lens formed without such compounds.

An embodiment relates to an improved gasket for engaging a mold. The gasket is preferably configured to engage a first mold set for forming a first lens of a first power. The gasket preferably includes at least four discrete projections for spacing mold members of a mold set. The projections are preferably arranged on an interior surface of the gasket. The projections are preferably evenly spaced around the interior surface of the gasket; in a preferred embodiment, the spacing between each projection is about 90 degrees.

In another embodiment, an improved gasket includes a fill port for receiving a lens forming composition while fully engaged to a mold set. The fill port preferably extends from an interior surface of the gasket to an exterior surface of the gasket. Consequently, the gasket need not be partially disengaged from a mold member of a mold set in order to receive a lens forming composition.

In another embodiment, a mold/gasket assembly for making plastic prescription lenses preferably includes a first mold set for forming a first lens of a first power and a gasket for engaging the first mold set. The first mold set may contain a front mold member and a back mold member. The back mold member is also known as the convex mold member. The back mold member preferably defines the concave surface of a convex lens. The gasket is preferably characterized by at least four discrete projections for spacing the front mold member from the back mold member. A mold cavity for retaining a lens forming composition is preferably at least partially defined by the front mold member, the back mold member, and the gasket. The back mold member preferably has a steep axis and a flat axis. Each of the projections preferably forms an oblique angle with the steep and the flat axis of the mold members. In a preferred embodiment, these angles may each be about 45 degrees. Since the gasket does not include a continuous lip along its interior surface for spacing mold members, as is conventional in the art, the gasket may be configured to engage a large variety of mold

sets. For example, the gasket may be configured to engage a second mold set for forming a second lens of a second power.

In another embodiment, a mold/gasket assembly for making plastic prescription lenses includes a mold set for forming a lens and a gasket configured to engage the mold set. The gasket is preferably characterized by a fill port for receiving a lens forming composition while the gasket is fully engaged to the mold. The fill port preferably extends from an interior surface to an exterior surface of the gasket. The mold set preferably contains at least a front mold member and a back mold member. A mold cavity for retaining a lens forming composition is preferably at least partially defined by the front mold member, the back mold member, and the gasket.

A method for making a plastic eyeglass lens is described. The method preferably includes engaging a gasket with a first mold set for forming a first lens of a first power. The first mold set preferably contains at least a front mold member and a back mold member. A mold cavity for retaining a lens forming composition may be at least partially defined by the front mold member, the back mold member, and the gasket. The gasket is preferably characterized by at least four discrete projections arranged on an interior surface thereof for spacing the front and back mold members. Engaging the gasket with the mold set preferably includes positioning the back mold members such that each of the projections forms an oblique angle with the steep and flat axis of the back mold member. In a preferred embodiment, this angle is about 45 degrees. The method preferably further includes introducing a lens forming composition into the mold cavity and curing the lens forming composition.

An additional embodiment provides a method for making a plastic eyeglass lens. The method preferably includes engaging a gasket with a first mold set for forming a first lens of a first power. The first mold set preferably contains at least a front mold member and a back mold member. A mold cavity for retaining a lens forming composition may

be at least partially defined by the front mold member, the back mold member, and the gasket. Preferably, the method further includes introducing a lens forming composition through a fill port, wherein the front and back mold members remain fully engaged with the gasket during the introduction of the lens forming composition. The lens forming composition may then be cured.

In an embodiment, a composition that includes two or more photochromic compounds may further include a light effector composition to produce a lens that exhibits an activated color that differs from an activated color produced by the photochromic compounds without the light effector composition. The activated color is defined as the color a lens achieves when exposed to a photochromic activating light source (e.g., sunlight). A photochromic activating light source is defined as any light source that produces light having a wavelength that causes a photochromic compound to become colored. Photochromic activating light is defined as light that has a wavelength capable of causing a photochromic compound to become colored. The photochromic activating wavelength band is defined as the region of light that has a wavelength that causes coloring of photochromic compounds. The light effector composition may include any compound that exhibits absorbance of at least a portion of the photochromic activating wavelength band. Light effector compositions may include photoinitiators, ultraviolet/visible light absorbers, ultraviolet light stabilizers, and dyes. In this manner, the activated color of a lens may be altered without altering the ratio and or composition of the photochromic compounds. By using a light effector composition, a single lens forming composition may be used as a base solution to which a light effector may be added in order to alter the activated color of the formed lens.

The addition of a light effector composition that absorbs photochromic activating light may cause a change in the activated color of the formed lens. The change in activated color may be dependent on the range of photochromic activating light absorbed by the light effector composition. The use of different light effector compositions may

allow an operator to produce photochromic lenses with a wide variety of activated colors (e.g., red, orange, yellow, green, blue, indigo, violet, gray, or brown).

In an embodiment, an ophthalmic eyeglass lens may be made from an activating light curable lens forming composition comprising a monomer composition and a photoinitiator composition. The monomer composition preferably includes a polyethylenic functional monomer. Preferably, the polyethylenic functional monomer composition includes an aromatic containing polyether polyethylenic functional monomer. In one embodiment, the polyethylenic functional monomer is preferably an ethoxylated bisphenol A di(meth)acrylate.

The monomer composition may include additional monomers to modify the properties of the formed eyeglass lens and/or the lens forming composition. Monomers which may be used in the monomer composition include polyethylenic functional monomers containing groups selected from acrylyl or methacrylyl.

In one embodiment, the photoinitiator composition preferably includes phenyl bis(2,4,6-trimethylbenzoyl) phosphine oxide, commercially available from Ciba Additives in Tarrytown, New York under the trade name of Irgacure 819. In another embodiment, the photoinitiator composition may include a mixture of photoinitiators. Preferably, a mixture of Irgacure 819 and 1-hydroxycyclohexylphenyl ketone, commercially available from Ciba Additives under the trade name of Irgacure 184, is used.

In another embodiment, an ophthalmic eyeglass lens may be made from an activating light curable lens forming composition comprising a monomer composition, a photoinitiator composition and a co-initiator composition. An activating light absorbing compound may also be present. An activating light absorbing compound is herein defined as a compound which absorbs at least a portion of the activating light. The

monomer composition preferably includes a polyethylenic functional monomer. Preferably, the polyethylenic functional monomer is an aromatic containing polyether polyethylenic functional monomer. In one embodiment, the polyethylenic functional monomer is preferably an ethoxylated bisphenol A di(meth)acrylate.

The co-initiator composition preferably includes amine co-initiators. Preferably, acrylyl amines are included in the co-initiator composition. In one embodiment, the co-initiator composition preferably includes a mixture of CN-384 and CN-386.

Examples of activating light absorbing compounds includes photochromic compounds, UV stabilizers, UV absorbers, and/or dyes.

In another embodiment, the controller is preferably configured to run a computer software program which, upon input of the eyeglass prescription, will supply the identification markings of the appropriate front mold, back mold and gasket. The controller may also be configured to store the prescription data and to use the prescription data to determine curing conditions. The controller may be configured to operate the curing unit to produce the appropriate curing conditions.

In one embodiment, the lens forming composition may be irradiated with continuous activated light to initiate curing of the lens forming composition. Subsequent to initiating the curing, the lens forming composition may be treated with additional activating light and heat to further cure the lens forming composition.

In another embodiment, the lens forming composition may be irradiated with continuous activated light in a heated curing chamber to initiate curing of the lens forming composition. Subsequent to initiating the curing, the lens forming composition may be treated with additional activating light and heat to further cure the lens forming composition.

In another embodiment, an apparatus for preparing an eyeglass lens is described. The apparatus includes a coating unit and a lens curing unit. The coating unit may be configured to coat either mold members or lenses. Preferably, the coating unit is a spin coating unit. The lens curing unit may be configured to substantially simultaneously direct activating light and heat toward mold members. The mold members are part of a mold assembly that may be placed within the lens curing unit. Depending on the type of lens forming composition used, the apparatus may be used to form photochromic and non-photochromic lenses. The apparatus is preferably configured to allow the operation of both the coating unit and the lens curing unit substantially simultaneously. The apparatus is also configured to allow curing, post-cure and anneal processes to be performed in the lens curing unit. The curing or post-cure processes may be performed substantially simultaneously with an anneal process within the lens curing apparatus.

In another embodiment, a system for dispensing a heated polymerizable lens forming composition is described. The dispensing system includes a body configured to hold the lens forming composition, a heating system coupled to the body for heating the monomer solution, a conduit coupled to the body for transferring the lens forming composition out of the body, and an elongated member positioned within the conduit for controlling the flow of the lens forming composition through the conduit. The elongated member is positionable within the conduit in a closed position such that flow of the lens forming composition through the conduit is inhibited. The elongated member may also be positioned within the conduit in an open position such that the lens forming composition flows through the conduit. An elastic member is preferably coupled to the elongated member. The elastic member exerts a force on the elongated member that causes the elongated member moves from the closed position positioned to the open position. A movable member is preferably coupled to the conduit and the elongated member. The movable member is preferably configured to control the position of the elongated member.

In another embodiment, a procedure for forming flat-top bifocal lenses is described. Flat-top bifocals include a far vision correction zone and a near vision correction region. The far vision correction zone is the portion of the lens which allows the user to see far away objects more clearly. The near vision correction zone is the region that allows the user to see nearby objects clearer. The near vision correction zone is characterized by a semicircular protrusion which extends out from the outer surface of an eyeglass lens. To reduce the incidence of premature release in flat-top bifocal lenses, it is preferred that polymerization of the lens forming composition in the front portion of the near vision correction zone is initiated before the portion of the lens forming composition in the far vision correction zone proximate the back mold member is substantially gelled. Preferably, this may be achieved by irradiating the front mold with activating light prior to irradiating the back mold with activating light. Alternatively, the incidence of premature release may also be reduced if the front portion of the near vision correction zone is gelled before gelation of the lens forming composition extends from the back mold member to the front mold member.

BRIEF DESCRIPTION OF THE DRAWINGS

The above brief description as well as further objects, features and advantages of the methods and apparatus of the present invention will be more fully appreciated by reference to the following detailed description of presently preferred but nonetheless illustrative embodiments in accordance with the present invention when taken in conjunction with the accompanying drawings in which:

Fig. 1 depicts a perspective view of a plastic lens forming apparatus.

Fig. 2 depicts a perspective view of a spin coating unit.

Fig. 3 depicts a cut-away side view of a spin coating unit.

Fig. 4 depicts a perspective view of a plastic lens forming apparatus with a portion of the body removed.

Fig. 5 depicts a perspective view of the components of a lens curing unit.

Fig. 6 depicts a perspective view of a plastic lens forming apparatus with a portion of the body removed and the coating units removed.

Fig. 7-10 depict various LCD filter patterns.

Fig. 11 depicts a mold assembly.

Fig. 12 depicts a post-cure unit.

Fig. 13 depicts a view of an embodiment of a heat source and a heat distributor.

Fig. 14 depicts a view of various embodiments of a heat source and heat distributors.

Fig. 15 depicts a view of an embodiment of a heat source and a heat distributor.

Fig. 16 depicts a view of an embodiment of two mold members and a gasket.

Fig. 17 depicts a plot of the temperature of the lens forming composition versus time during the application of activating light pulses.

Fig. 18 depicts a schematic diagram of a lens curing apparatus with a light sensor

and controller.

Fig. 19 depicts a view of an embodiment of a system simultaneously employing both a flash light source and a continuous activating (e.g., fluorescent) light source.

Fig. 20 depicts an embodiment of a system simultaneously employing two flash light sources.

Fig. 21 depicts an embodiment of a system employing an activating light controller.

Fig. 22 depicts a graph illustrating a temperature profile of a continuous radiation cycle.

Fig. 23 depicts a graph illustrating temperature profiles for a continuous irradiation cycle and a pulse irradiation cycle employed with a mold/gasket set having a 3.00D base curve, and while applying cooled air at 58 ° F to the mold/gasket set.

Fig. 24 depicts a chart illustrating qualitative relationships among curing cycle variables.

Fig. 25 depicts a graph illustrating temperature profiles for one curing cycle for a mold/gasket set having a 6.00D base curve and used with three different light levels.

Fig. 26 depicts a graph illustrating continuous and pulsed temperature profiles for a curing cycle employing a mold/gasket set with a 6.00D base curve.

Fig. 27 depicts a graph illustrating continuous and pulsed temperature profiles for a curing cycle employing a mold/gasket set with a 4.50D base curve.

Fig. 28 depicts a graph illustrating continuous and pulsed temperature profiles for a curing cycle employing a mold/gasket set with a 3.00D base curve.

Fig. 29 depicts a cross sectional view of a flat-top bifocal mold.

Fig. 30 depicts a plot of % transmittance of light versus wavelength for a photochromic lens.

Fig. 31 depicts a plot of % transmittance of light versus wavelength for both a colorless lens containing ultraviolet/visible light absorbers and a lens containing no ultraviolet/visible light absorbers.

Fig. 32 depicts an isometric view of an embodiment of a gasket.

Fig. 33 depicts a top view of the gasket of Fig. 1.

Fig. 34 depicts a cross-sectional view of an embodiment of a mold/gasket assembly.

Fig. 35 depicts an isometric view of an embodiment of a gasket.

Fig. 36 depicts a top view of the gasket of Fig. 4.

Fig. 37 depicts a graph showing the absorption ranges of a variety of photochromic compounds and light effectors.

Fig. 38 depicts a plastic lens forming apparatus which includes two lens curing units.

Fig. 39 depicts chemical structure of acrylated amines.

Figs. 40 - 42 depict a front panel of a controller with a display screen depicting various display menus.

Fig. 43 depicts a cross-sectional side view of a heated polymerizable lens forming composition dispensing system.

Fig. 44-46 depict cross-sectional side views of a conduit for a heated polymerizable lens forming composition dispensing system.

Fig. 47 depicts a cross-sectional perspective view of a movable member for a heated polymerizable lens forming composition dispensing system.

Fig. 48 depicts a cross-sectional side view of a movable member for a heated polymerizable lens forming composition dispensing system.

Fig. 49 depicts a topographical view of a groove formed in a movable member for a heated polymerizable lens forming composition dispensing system.

Fig. 50 depicts a side view of a heated polymerizable lens forming composition dispensing system mounted on a platform.

Fig. 51 depicts a front view of a lens curing unit.

Fig. 52 depicts a top view of a lens curing unit.

Fig. 53 depicts a mold assembly for making flat-top bifocal lenses.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Apparatus, operating procedures, equipment, systems, methods, and compositions for lens curing using activating light are available from Rapid Cast, Inc., Q2100, Inc., and Fast Cast, Inc. in Louisville, Kentucky.

Referring now to Fig. 1, a plastic lens curing apparatus is generally indicated by reference numeral 10. As shown in Fig. 1, lens forming apparatus 10 includes at least one coating unit 20, a lens curing unit 30, a post-cure unit 40, and a controller 50. Preferably, apparatus 10 includes two coating units 20. Coating unit 20 is preferably configured to apply a coating layer to a mold member or a lens. Preferably, coating unit 20 is a spin coating unit. Lens curing unit 30 includes an activating light source for producing activating light. As used herein "activating light" means light that may affect a chemical change. Activating light may include ultraviolet light (e.g., light having a wavelength between about 300 nm to about 400 nm), actinic light, visible light or infrared light. Generally, any wavelength of light capable of affecting a chemical change may be classified as activating. Chemical changes may be manifested in a number of forms. A chemical change may include, but is not limited to, any chemical reaction that causes a polymerization to take place. Preferably the chemical change causes the formation of an initiator species within the lens forming composition, the initiator species being capable of initiating a chemical polymerization reaction. The activating light source is preferably configured to direct light toward a mold assembly. Post-cure unit 40 is preferably configured to complete the polymerization of plastic lenses. Post-cure unit 40 preferably includes an activating light source and a heat source. Controller 50 is preferably a programmable logic controller. Controller 50 is preferably coupled to coating units 20, lens curing unit 30, and post-cure unit 40, such that the controller is capable of substantially simultaneously operating the three units 20, 30, and 40. Controller 50 may be a computer.

A coating unit for applying a coating composition to a lens or a mold member and then curing the coating composition is described in U.S. Patents 4,895,102 to Kachel et al., 3,494,326 to Upton, and 5,514,214 to Joel et al. (all of which are incorporated herein by reference). In addition, the apparatus shown in Figs. 2 and 3 may also be used to apply coatings to lenses or mold members.

Fig. 2 depicts a pair of spin coating units 102 and 104. These spin coating units may be used to apply a scratch resistant coating or a tint coating to a lens or mold member. Each of the coating units includes an opening through which an operator may apply lenses and lens mold assemblies to a holder 108. Holder 108 is preferably partially surrounded by barrier 114. Barrier 114 is preferably coupled to a dish 115. As shown in Fig. 3, the dish edges may be inclined to form a peripheral sidewall 121 that merges with barrier 114. The bottom 117 of the dish is preferably substantially flat. The flat bottom preferably has a circular opening that allows an elongated member 109 coupled to lens holder 108 to extend through the dish 115.

Holder 108 is preferably coupled to a motor 112 via elongated member 109. Motor 112 is preferably configured to cause rotation of holder 108. In such a case, motor 112 is preferably configured to cause rotation of elongated member 109, that in turn causes the rotation of holder 108. The coating unit 102/104, may also include an electronic controller 140. Electronic controller 140 is preferably coupled to motor 112 to control the rate at which holder 108 is rotated by motor 112. Electronic controller 140 may be coupled to a programmable logic controller, such as controller 50, shown in Fig. 1. The programmable logic controller may send signals to the electronic controller to control the rotational speed of holder 108. Preferably, motor 112 is configured to rotate holder 108 at different rates. Motor 112 is preferably capable of rotating the lens or mold member at a rate of up to 1500 revolutions per minute ("RPM").

In one embodiment, barrier 114 has an interior surface that may be made or lined

with an absorbent material such as foam rubber. Preferably, this absorbent material is disposable and removable. The absorbent material absorbs any liquids that fall off a lens or mold member during use. Alternatively, the interior surface of barrier 114 may be substantially non-absorbent, allowing any liquids used during the coating process to move down barrier 114 into dish 115.

Coating units 20, are preferably positioned in a top portion 12 of lens forming apparatus 10, as depicted in Fig. 1. A cover 22 is preferably coupled to body 14 of the lens forming apparatus to allow top portion 12 to be covered during use. A light source 23 is preferably positioned on an inner surface of cover 22. The light source includes at least one lamp 24, preferably two or more lamps, positioned on the inner surface of cover 22. Lamps 24 may be positioned such that the lamps are oriented above the coating units 20 when cover 22 is closed. Lamps 24 preferably emit activating light upon the lenses or mold members positioned within coating units 20. Lamps may have a variety of shapes including, but not limited to, linear (as depicted in Fig. 1), square, rectangular, circular, or oval. Activating light sources preferably emit light having a wavelength that will initiate curing of various coating materials. For example, most currently used coating materials are preferably curable by activating light having wavelengths in the ultraviolet region, therefore the light sources should exhibit strong ultraviolet light emission. The light sources should, preferably, produce minimal heat during use. Thus, lamps 24 will preferably have low heat output. Lamps that exhibit strong ultraviolet light emission have a peak output at a wavelength in the ultraviolet light region, between about 200 nm to about 400 nm, preferably the peak output is between about 200 nm to 300 nm, and more preferably at about 254 nm. In one embodiment, lamps 24 may be lamps that have a peak output in the ultraviolet light region, and have relatively low heat output. Such lights are commonly known as "germicidal" lights and any such light may be used. A "germicidal" light emitting light with a peak output in the desired ultraviolet region is commercially available from Voltarc, Inc. of Fairfield, Connecticut as model UV-WX G10T5.

An advantage of using a spin coating unit is that lamps of a variety of shapes may be used (e.g., linear lamps) for the curing of the coating materials. In one embodiment, a coating material is preferably cured in a substantially uniform manner to ensure that the coating is formed uniformly on the mold member or lens. With a spin coating unit, the object to be coated may be spun at speeds high enough to ensure that a substantially uniform distribution of light reaches the object during the curing process, regardless of the shape of the light source. The use of a spin coating unit preferably allows the use of commercially available linear light sources for the curing of coating materials.

A switch may be incorporated into cover 22. The switch is preferably electrically coupled to light source 23 such that the switch must be activated prior to turning the light source on. Preferably, the switch is positioned such that closing the cover causes the switch to become activated. In this manner, the lights will preferably remain off until the cover is closed, thus preventing inadvertent exposure of an operator to the light from light source 23.

During use a lens or lens mold assembly may be placed on the lens holder 108. The lens holder 108 may include a suction cup connected to a metal bar. The concave surface of the suction cup may be attachable to a face of a mold or lens, and the convex surface of the suction cup may be attached to a metal bar. The metal bar may be coupled to motor 112. The lens holder may also include movable arms and a spring assembly that may be together operable to hold a lens against the lens holder with spring tension during use.

As shown in Fig. 4, the curing unit 30 may include an upper light source 214, a lens drawer assembly 216, and a lower light source 218. Lens drawer assembly 216 preferably includes a mold assembly holder 220, more preferably at least two mold assembly holders 220. Each of the mold assembly holders 220 is preferably configured

plastic lenses. The formed plastic lenses exhibit a gray or brown color in the presence of a photochromic activating light source. Crano et. al., describes the use of two or more organic photochromic compounds within a plastic lens. One of the organic photochromic compounds exhibits an absorption maximum in the range between about 590 nm to about 700 nm in the presence of a photochromic activating light source. The other organic photochromic compound exhibits an absorption maximum in the range between about 400 nm and less than about 500 nm. The ratios of the compounds may be varied to produce lenses which exhibit a variety of activated colors. Typically, either the ratios of the photochromic compounds or the specific photochromic compound used may be varied to effect a change in the activated color of the lens.

In an embodiment, a composition which includes two or more photochromic compounds may further include a light effector composition to produce a lens which exhibits an activated color which differs from an activated color produced by the photochromic compounds without the light effector composition. The light effector composition may include any compound which absorbs photochromic activating light. Light effector compositions may include photoinitiators, non-photochromic ultraviolet/visible light absorbers (as defined above), non-photochromic dyes, and ultraviolet light stabilizers. In this manner, the activated color of a lens may be altered without altering the ratio and or composition of the photochromic compounds. This may be particularly important when large batches of lens forming compositions are prepared before use. If photochromic lenses which exhibit a variety of activated colors are to be produced, it is typically necessary to create a separate lens forming composition for each colored lens. By using a light effector composition, a single lens forming composition may be used as a base solution to which a light effector may be added in order to alter the activated color of the formed lens.

The activated color of a photochromic lens may be determined by the visible light absorption of the photochromic compounds in their colored state. When two

to hold a pair of mold members that together with a gasket form a mold assembly. The lens drawer assembly 216 is preferably slidingly mounted on a guide. During use, mold assemblies may be placed in the mold assembly holders 220 while the lens drawer assembly is in the open position (i.e., when the door extends from the front of the lens curing unit). After the mold assemblies have been loaded into the mold holder 220 the door may be slid into a closed position, with the mold assemblies directly under the upper light source 214 and above the lower light source 218. Vents (not shown) may be placed in communication with the lens curing unit to allow a stream of air to be directed toward the mold members when the mold members are positioned beneath the upper lamps. An exhaust fan (not shown) may communicate with the vents to improve the circulation of air flowing through the lens curing unit.

As shown in Figs. 4 and 5, it is preferred that the upper light source 214 and lower light source 216 include a plurality of activating light generating devices or lamps 240. Preferably, the lamps are oriented proximate each other to form a row of lights, as depicted in Fig. 4. Preferably, three or four lamps are positioned to provide substantially uniform radiation over the entire surface of the mold assembly to be cured. The lamps 240, preferably generate activating light. Lamps 240 may be supported by and electrically connected to suitable fixtures 242. Lamps 240 may generate either ultraviolet light, actinic light, visible light, and/or infrared light. The choice of lamps is preferably based on the monomers used in the lens forming composition. In one embodiment, the activating light may be generated from a fluorescent lamp. The fluorescent lamp preferably has a strong emission spectra in the 380 to 490 nm region. A fluorescent lamp emitting activating light with the described wavelengths is commercially available from Philips as model TLD-15W/03. In another embodiment, the lamps may be ultraviolet lights.

In one embodiment, the activating light sources may be turned on and off quickly between exposures. Flasher ballasts 250, depicted in Fig. 6, may be used for this

function. The flasher ballast may be positioned beneath the coating unit. A flasher ballast 250 may operate in a standby mode wherein a low current is supplied to the lamp filaments to keep the filaments warm and thereby reduce the strike time of the lamp. Such a ballast is commercially available from Magnatek, Inc of Bridgeport, Connecticut. Power supply 252 may also be located proximate the flasher ballasts, underneath the coating unit.

Fig. 18 schematically depicts a light control system. The light sources 214 in lens curing unit 30 apply light towards the mold assembly 352. A light sensor 700 may be located adjacent the light sources 214. Preferably, the light sensor 700 is a photoresistor light sensor (photodiodes or other light sensors may also be usable in this application). The light sensor 700 with a filter 750 may be connected to lamp driver 702 via wires 704. Lamp driver 702 sends a current through the light sensor 700 and receives a return signal from the light sensor 700. The return signal may be compared against an adjustable set point, and then the electrical frequency sent to the light sources 214 via wires 706 may be varied depending on the differences between the set point and the signal received from the light sensor 700. Preferably, the light output is maintained within about +/- 1.0 percent.

One "lamp driver" or light controller is a Mercron Model FX0696-4 and Model FX06120-6 (Mercron, Inc., Dallas, Texas, U.S.A.). These light controllers are described in U.S. patents 4,717,863 and 4,937,470.

In an embodiment, a flash lamp emits activating light pulses to cure the lens forming material. It is believed that a flash lamp would provide a smaller, cooler, less expensive, and more reliable light source than other sources. The power supply for a flash lamp tends to draw relatively minimal current while charging its capacitor bank. The flash lamp discharges the stored energy on a microsecond scale to produce very high peak intensities from the flash tube itself. Thus flash lamps tend to require less power for

operation and generate less heat than other light sources used for activating light curing. A flash lamp may also be used to cure a lens coating.

In an embodiment, the flash lamp used to direct activating light toward at least one of the mold members is a xenon light source. The lens coating may also be cured using a xenon light source. Referring to Fig. 21, xenon light source 980 preferably contains photostrobe 992 having a tube 996 and electrodes to allow the transmission of activating light. The tube may include borosilicate glass or quartz. A quartz tube will generally withstand about 3 to 10 times more power than a hard glass tube. The tube may be in the shape of a ring, U, helix, or it may be linear. The tube may include capacitive trigger electrode 995. The capacitive trigger electrode may include a wire, silver strip, or conductive coating located on the exterior of tube 996. The xenon light source is preferably adapted to deliver pulses of light for a duration of less than about 1 second, more preferably between about 1/10 of a second and about 1/1000 of a second, and more preferably still between about 1/400 of a second and 1/600 of a second. The xenon source may be adapted to deliver light pulses about every 4 seconds or less. The relatively high intensity of the xenon lamp and short pulse duration may allow rapid curing of the lens forming composition without imparting significant radiative heat to the composition.

In an embodiment, controller 990 (shown in Fig. 21) controls the intensity and duration of activating light pulses delivered from activating light source 980 and the time interval between pulses, shown in Fig. 19. Activating light source 980 may include capacitor 994, that stores the energy required to deliver the pulses of activating light. Capacitor 994 may be adapted to allow pulses of activating light to be delivered as frequently as desired. Temperature monitor 997 may be located at a number of positions within mold chamber 984. The temperature monitor may measure the temperature within the chamber and/or the temperature of air exiting the chamber. The system may be configured to send a signal to cooler 988 and/or distributor 986 (shown in Fig. 19) to vary

the amount and/or temperature of the cooling air. The temperature monitor may also determine the temperature at any of a number of locations proximate the mold cavity and send a signal to controller 990 to vary the pulse duration, pulse intensity, or time between pulses as a function of a temperature within mold chamber 984.

In an embodiment, light sensor 999 may be used to determine the intensity of activating light emanating from source 980. The light sensor is preferably configured to send a signal to controller 990, that is preferably configured to maintain the intensity of the activating light at a selected level. Filter 998 may be positioned between activating light source 980 and light sensor 999 and is preferably configured to inhibit non-activating light rays from contacting light sensor 999, while allowing activating rays to contact the sensor. In one embodiment, the filter may include 365 N glass or any other material adapted to filter non-activating light (e.g., visible light) and transmit activating light.

In an embodiment, more than one activating light source may be used to simultaneously apply activating pulses to the lens forming composition. Such an embodiment is shown in Fig. 20. Activating light sources 980a and 980b may be positioned around mold chamber 985 so that pulses may be directed toward the front face of a lens and the back face of a lens substantially simultaneously. Mold chamber 985 is preferably adapted to hold a mold in a vertical position such that pulses from activating light source 980a may be applied to the face of a first mold member, while pulses from activating light source 980b may be applied to the face of a second mold member. In an embodiment, activating light source 980b applies activating light pulses to a back surface of a lens more frequently than xenon source 980a applies activating light pulses to a front surface of a lens. Activating light sources 980a and 980b may be configured such that one source applies light to mold chamber 984 from a position above the chamber while the other activating light source applies light to the mold chamber from a position below the chamber.

In an embodiment, a xenon light source and a relatively low intensity (e.g., fluorescent) light source may be used to simultaneously apply activating light to a mold chamber. As illustrated in Fig. 19, xenon source 980 may apply activating light to one side of mold chamber 984 while low intensity fluorescent source 982 applies activating light to another side of the mold chamber. Fluorescent source 982 may include a compact fluorescent "light bucket" or a diffused fluorescent lamp. The fluorescent light source may deliver continuous or substantially pulsed activating light as the xenon source delivers activating light pulses. The fluorescent source may deliver continuous activating light rays having a relatively low intensity of less than about 100 microwatts/cm^2.

In one embodiment, an upper light filter 254 may be positioned between upper light source 214 and lens drawer assembly 216, as depicted in Fig. 5. A lower light filter 256 may be positioned between lower light source 218 and lens drawer assembly 216. The upper light filter 254 and lower light filter 256 are shown in Fig. 5 as being made of a single filter member, however, those of ordinary skill in the art will recognize that each of the filters may include two or more filter members. The components of upper light filter 254 and lower light filter 256 are preferably modified depending upon the characteristics of the lens to be molded. For instance, in an embodiment for making negative lenses, the upper light filter 254 includes a plate of Pyrex glass that may be frosted on both sides resting upon a plate of clear Pyrex glass. The lower light filter 256 includes a plate of Pyrex glass, frosted on one side, resting upon a plate of clear Pyrex glass with a device for reducing the intensity of activating light incident upon the center portion relative to the edge portion of the mold assembly.

Conversely, in a preferred arrangement for producing positive lenses, the upper light filter 254 includes a plate of Pyrex glass frosted on one or both sides and a plate of clear Pyrex glass resting upon the plate of frosted Pyrex glass with a device for reducing the intensity of activating light incident upon the edge portion in relation to the center

portion of the mold assembly. The lower light filter 256 includes a plate of clear Pyrex glass frosted on one side resting upon a plate of clear Pyrex glass with a device for reducing the intensity of activating light incident upon the edge portion in relation to the center portion of the mold assembly. In this arrangement, in place of a device for reducing the relative intensity of activating light incident upon the edge portion of the lens, the diameter of the aperture 250 may be reduced to achieve the same result, i.e., to reduce the relative intensity of activating light incident upon the edge portion of the mold assembly.

It should be apparent to those skilled in the art that each filter 254 or 256 could be composed of a plurality of filter members or include any other means or device effective to reduce the light to its desired intensity, to diffuse the light and/or to create a light intensity gradient across the mold assemblies. Alternately, in certain embodiments no filter elements may be used.

In one embodiment, upper light filter 254 or lower light filter 256 each include at least one plate of Pyrex glass having at least one frosted surface. Also, either or both of the filters may include more than one plate of Pyrex glass each frosted on one or both surfaces, and/or one or more sheets of tracing paper. After passing through frosted Pyrex glass, the activating light is believed to have no sharp intensity discontinuities. By removing the sharp intensity distributions a reduction in optical distortions in the finished lens may be achieved. Those of ordinary skill in the art will recognize that other means may be used to diffuse the activating light so that it has no sharp intensity discontinuities.

In another embodiment, upper light filter 254 and lower light filter 256 may be liquid crystal display ("LCD") panels. Preferably, the LCD panel is a monochrome trans-flective panel with the back light and reflector removed. A monochrome trans-flective LCD panel is manufactured by Sharp Corporation and may be purchased from Earth Computer Products. The LCD panels are preferably positioned such that light from the

light sources passes through the LCD panels to the lens drawer assembly 216. The intensity of the light is preferably reduced as the light passes through the LCD panel. The LCD panel is preferably programmable such that the light transmissibility of the LCD panel may be altered. In use, a predetermined pattern of light and dark regions may be displayed on the LCD panel. As light from the light sources hits these regions the light may be transmitted through the light regions with a higher intensity than through the darker regions. In this manner, the pattern of light and dark areas on the LCD panel may be manipulated such that light having the optimal curing intensity pattern hits the mold assemblies. Although the LCD panel is not entirely opaque in its blackened out state, it may still reduce the intensity of light reaching the mold assemblies. Typically, the light transmission ratio between the lightest and darkest regions of the LCD panel is about 4 to 1.

The use of an LCD panel as a light filter offers a number of advantages over the conventional filter systems described earlier. One advantage is that the filter pattern may be changed actively during a curing cycle. For example, the pattern of light and dark regions may be manipulated such that a lens is initially cured from the center of the lens then the curing may be gradually expanded to the outer edges of the lens. This type of curing pattern may allow a more uniformly cured lens to be formed. In some instances, curing in this manner may also be used to alter the final power of the formed lens.

Another advantage is that the LCD panel may be used as a partial shutter to reduce the intensity of light reaching the mold assembly. By blackening the entire LCD panel the amount of light reaching any portion of the mold assembly may be reduced. In this manner, the LCD may be used to create "pulses" of light by alternating between a transmissive and darkened mode. By having the LCD panel create these light "pulses" a flash ballast or similar pulse generating equipment may be unnecessary. Thus, the light sources may remain on during the entire curing cycle, with the LCD panel creating the curing light pulses. This may also increase the lifetime of the lamps, since the rapid

cycling of lamps tends to reduce the lamps' lifetime.

In another embodiment, an LCD panel may be used to allow different patterns and/or intensities of light to reach two separate mold assemblies. As depicted in Fig. 4, the lens curing unit may be configured to substantially simultaneously irradiate two mold assemblies. If the mold assemblies are being used to create lenses having the same power the light irradiation pattern and/or intensity may be substantially the same for each mold assembly. If the mold assemblies are being used to create lenses having significantly different powers, each mold assembly may require a significantly different light irradiation pattern and/or intensity. The use of an LCD filter may allow the irradiation of each of the mold assemblies to be controlled individually. For example, a first mold assembly may require a pulsed curing scheme, while the other mold assembly may require a continuous irradiation pattern through a patterned filter. The use of an LCD panel may allow such lenses to be formed substantially simultaneously. A first portion of the LCD panel between the light source and the first molding apparatus may be alternatively switched between a darkened and an undarkened state. While a first portion is used to create pulses of activating light, another portion of the LCD panel may be formed into the specific pattern required for the continuous curing of the other lens.

When non-LCD type filters are used it may be necessary to maintain a library of filters for use in the production of different types of prescription lenses. Typically, each individual prescription will need a particular filter pattern to obtain a high quality lens. Since an LCD panel may be programmed into a variety of patterns, it may be possible to rely on a single LCD panel, rather than a library of filters. The LCD panel may be programmed to fit the needs of the specific type of lens being formed. Such a system also minimizes the need for human intervention, since a controller may be programmed for a desired pattern, rather than the operator having to choose among a "library" of filters.

The control of the temperature of an LCD panel filter during a curing cycle may

be important for achieving a proper lens. In general as the temperature of a panel is increased the lighter regions of the panel may become darker (i.e., less light transmissive). Thus, it may be necessary to control the temperature of the LCD panel during curing to ensure that light having the appropriate intensity reaches the mold assemblies. A cooling system or heating system may therefore, be coupled to the LCD panel to ensure proper temperature control. In one embodiment, it is preferred that a substantially transparent heater is attached to the LCD panel. By increasing the temperature of the LCD panel the light transmissibility of the panel may be decreased. It is preferred that an LCD panel be maintained above room temperature since at room temperature the panel may be too light to sufficiently inhibit the light from reaching the mold assemblies. In order to obtain a proper pattern of light and dark regions when the LCD panel is heated it may be necessary to adjust the contrast of the panel. This adjustment may be done either manually or electronically.

The LCD panel filters may be coupled to a programmable logic device that may be used to design and store patterns for use during curing. Fig. 7–10 show a number of patterns which may be generated on an LCD panel and used to filter activating light. Each of these patterns is preferably used for the production of a lens having a specific prescription power.

As shown in Fig. 11, the mold assembly 352 may include opposed mold members 378, separated by an annular gasket 380 to define a lens molding cavity 382. The opposed mold members 378 and the annular gasket 380 may be shaped and selected in a manner to produce a lens having a desired diopter.

The mold members 378 may be formed of any suitable material that will permit the passage of activating light. The mold members 378 are preferably formed of glass. Each mold member 378 has an outer peripheral surface 384 and a pair of opposed surfaces 386 and 388 with the surfaces 386 and 388 being precision ground. Preferably

the mold members 378 have desirable activating light transmission characteristics and both the casting surface 386 and non-casting surface 388 preferably have no surface aberrations, waves, scratches or other defects as these may be reproduced in the finished lens.

As noted above, the mold members 378 are preferably adapted to be held in spaced apart relation to define a lens molding cavity 382 between the facing surfaces 386 thereof. The mold members 378 are preferably held in a spaced apart relation by a T-shaped flexible annular gasket 380 that seals the lens molding cavity 382 from the exterior of the mold members 378. In use, the gasket 380 may be supported on a portion of the mold assembly holder 220 (shown in Fig. 4).

In this manner, the upper or back mold member 390 has a convex inner surface 386 while the lower or front mold member 392 has a concave inner surface 386 so that the resulting lens molding cavity 382 is preferably shaped to form a lens with a desired configuration. Thus, by selecting the mold members 378 with a desired surface 386, lenses with different characteristics, such as focal lengths, may be produced.

Rays of activating light emanating from lamps 240 preferably pass through the mold members 378 and act on a lens forming material disposed in the mold cavity 382 in a manner discussed below so as to form a lens. As noted above, the rays of activating light may pass through a suitable filter 254 or 256 before impinging upon the mold assembly 352.

The mold members 378, preferably, are formed from a material that will not transmit activating light having a wavelength below approximately 300 nm. Suitable materials are Schott Crown, S-1 or S-3 glass manufactured and sold by Schott Optical Glass Inc., of Duryea, Pennsylvania or Corning 8092 glass sold by Corning Glass of Corning, New York. A source of flat-top or single vision molds may be Augen Lens Co.

in San Diego, California.

The annular gasket 380 may be formed of vinyl material that exhibits good lip finish and maintains sufficient flexibility at conditions throughout the lens curing process. In an embodiment, the annular gasket 380 is formed of silicone rubber material such as GE SE6035 which is commercially available from General Electric. In another preferred embodiment, the annular gasket 380 is formed of copolymers of ethylene and vinyl acetate which are commercially available from E. I. DuPont de Nemours & Co. under the trade name ELVAX7. Preferred ELVAX7 resins are ELVAX7 350 having a melt index of 17.3-20.9 dg/min and a vinyl acetate content of 24.3-25.7 wt. %, ELVAX7 250 having a melt index of 22.0-28.0 dg/min and a vinyl acetate content of 27.2-28.8 wt. %, ELVAX7 240 having a melt index of 38.0-48.0 dg/min and a vinyl acetate content of 27.2-28.8 wt. %, and ELVAX7 150 having a melt index of 38.0-48.0 dg/min and a vinyl acetate content of 32.0-34.0 wt. %. In another embodiment, the gasket may be made from polyethylene. Regardless of the particular material, the gaskets 80 may be prepared by conventional injection molding or compression molding techniques which are well-known by those of ordinary skill in the art.

In another embodiment, Figs. 32 and 33 present an isometric view and a top view, respectively, of a gasket 510. Gasket 510 may be annular, and is preferably configured to engage a mold set for forming a mold assembly. Gasket 510 is preferably characterized by at least four discrete projections 511. Gasket 510 preferably has an exterior surface 514 and an interior surface 512. The projections 511 are preferably arranged upon inner surface 512 such that they are substantially coplanar. The projections are preferably evenly spaced around the interior surface of the gasket Preferably, the spacing along the interior surface of the gasket between each projection is about 90 degrees. Although four projections are preferred, it is envisioned that more than four could be incorporated. The gasket 510 may be formed of a silicone rubber material such as GE SE6035 which is commercially available from General Electric. In another

embodiment, the gasket 510 may be formed of copolymers of ethylene and vinyl acetate which are commercially available from E. I. DuPont de Nemours & Co. under the trade name ELVAX7. In another embodiment, the gasket 510 may be formed from polyethylene.

As shown in Fig. 34, projections 511 are preferably capable of spacing mold members 526 of a mold set. Mold members 526 may be any of the various types and sizes of mold members that are well known in the art. A mold cavity 528 at least partially defined by mold members 526 and gasket 510, is preferably capable of retaining a lens forming composition. Preferably, the seal between gasket 510 and mold members 526 is as complete as possible. The height of each projection 511 preferably controls the spacing between mold members 526, and thus the thickness of the finished lens. By selecting proper gaskets and mold sets, lens cavities may be created to produce lenses of various powers.

A mold assembly consists of two mold members. A front mold member 526a and a back mold member 526b, as depicted in Fig. 34. The back mold member is also known as the convex mold member. The back mold member preferably defines the concave surface of a convex lens. Referring back to Figs. 32 and 33, locations where the steep axis 522 and the flat axis 524 of the back mold member 526b preferably lie in relation to gasket 510 have been indicated. In conventional gaskets, a raised lip may be used to space mold members. The thickness of this lip varies over the circumference of the lip in a manner appropriate with the type of mold set a particular gasket is designed to be used with. In order to have the flexibility to use a certain number of molds, an equivalent amount of conventional gaskets is typically kept in stock.

However, within a class of mold sets there may be points along the outer curvature of a the back mold member where each member of a class of back mold members is shaped similarly. These points may be found at locations along gasket 510,

oblique to the steep and flat axes of the mold members. In a preferred embodiment, these points are at about 45 degree angles to the steep and flat axes of the mold members. By using discrete projections 511 to space the mold members at these points, an individual gasket could be used with a variety of mold sets. Therefore, the number of gaskets that would have to be kept in stock may be greatly reduced.

In addition, gasket 510 may include a recession 518 for receiving a lens forming composition. Lip 520 may be pulled back in order to allow a lens forming composition to be introduced into the cavity. Vent ports 516 may be incorporated to facilitate the escape of air from the mold cavity as a lens forming composition is introduced.

A method for making a plastic eyeglass lenses using gasket 510 is presented. The method preferably includes engaging gasket 510 with a first mold set for forming a first lens of a first power. The first mold set preferably contains at least a front mold member 526a and a back mold member 526b. A mold cavity for retaining a lens forming composition may be at least partially defined by mold members 526a and 526b and gasket 510. Gasket 510 is preferably characterized by at least four discrete projections 511 arranged on interior surface 512 for spacing the mold members. Engaging gasket 510 with the mold set preferably includes positioning the mold members such that each of the projections 511 forms an oblique angle with the steep and flat axis of the back mold member 526b. In a preferred embodiment, this angle is about 45 degrees. The method preferably further includes introducing a lens forming composition into mold cavity 528 and curing the lens forming composition. Curing may include exposing the composition to activating light and/or thermal radiation. After the lens is cured, the first mold set may be removed from the gasket and the gasket may then be engaged with a second mold set for forming a second lens of a second power.

Figs. 35 and 36 present an isometric view and a top view, respectively, of an improved gasket. Gasket 530 may be composed of similar materials as gasket 510. Like

gasket 510, gasket 530 is preferably annular, but may be take a variety of shapes. In addition, gasket 530 may incorporate projections 531 in a manner similar to the projections 511 shown in Fig. 32. Alternatively, gasket 530 may include a raised lip along interior surface 532 or another method of spacing mold members that is conventional in the art.

Gasket 530 preferably includes a fill port 538 for receiving a lens forming composition while gasket 530 is fully engaged to a mold set. Fill port 538 preferably extends from interior surface 532 of gasket 530 to an exterior surface 534 of gasket 530. Consequently, gasket 530 need not be partially disengaged from a mold member of a mold set in order to receive a lens forming composition. In order to introduce a lens forming composition into the mold cavity defined by a conventional mold/gasket assembly the gasket must be at least partially disengaged from the mold members. During the process of filling the mold cavity, lens forming composition may drip onto the backside of a mold member. Lens forming composition on the backside of a mold member may cause activating light used to cure the lens to become locally focused, and may cause optical distortions in the final product. Because fill port 538 allows lens forming composition to be introduced into a mold cavity while gasket 530 is fully engaged to a mold set, gasket 530 preferably avoids this problem. In addition, fill port 538 may be of sufficient size to allow air to escape during the introduction of a lens forming composition into a mold cavity; however, gasket 530 may also incorporate vent ports 536 to facilitate the escape of air.

A method for making a plastic eyeglass lens using gasket 530 preferably includes engaging gasket 530 with a first mold set for forming a first lens of a first power. The first mold set preferably contains at least a front mold member and a back mold member. A mold cavity for retaining a lens forming composition may be at least partially defined by the front mold member, the back mold member, and the gasket. Preferably, the method further includes introducing a lens forming composition through fill port 538,

wherein the first and second mold members remain fully engaged with the gasket during the introduction of the lens forming composition. The lens forming composition may then be cured by use of activating light and/or thermal radiation.

In operation, the apparatus may be appropriately configured for the production of positive lenses which are relatively thick at the center or negative lenses which are relatively thick at the edge. To reduce the likelihood of premature release, the relatively thick portions of a lens are preferably polymerized at a faster rate than the relatively thin portions of a lens.

The rate of polymerization taking place at various portions of a lens may be controlled by varying the relative intensity of activating light incident upon particular portions of a lens. The rate of polymerization taking place at various portions of a lens may also be controlled by directing air across the mold members 378 to cool the mold assembly 352.

For positive lenses, the intensity of incident activating light is preferably reduced at the edge portion of the lens so that the thicker center portion of the lens polymerizes faster than the thinner edge portion of the lens. Conversely, for a negative lens, the intensity of incident activating light is preferably reduced at the center portion of the lens so that the thicker edge portion of the lens polymerizes faster than the thinner center portion of the lens. For either a positive lens or a negative lens, air may be directed across the faces of the mold members 378 to cool the mold assembly 352. As the overall intensity of incident activating light is increased, more cooling is needed which may be accomplished by either or both of increasing the velocity of the air and reducing the temperature of the air.

It is well known by those of ordinary skill in the art that lens forming materials tend to shrink as they cure. If the relatively thin portion of a lens is allowed to

polymerize before the relatively thick portion, the relatively thin portion will tend to be rigid at the time the relatively thick portion cures and shrinks and the lens will either release prematurely from or crack the mold members. Accordingly, when the relative intensity of activating light incident upon the edge portion of a positive lens is reduced relative to the center portion, the center portion may polymerize faster and shrink before the edge portion is rigid so that the shrinkage is more uniform. Conversely, when the relative intensity of activating light incident upon the center portion of a negative lens is reduced relative to the edge portion, the edge portion may polymerize faster and shrink before the center becomes rigid so that the shrinkage is more uniform.

The variation of the relative intensity of activating light incident upon a lens may be accomplished in a variety of ways. According to one method, in the case of a positive lens, a ring of opaque material may be placed between the lamps and the mold assembly so that the incident activating light falls mainly on the thicker center portion of the lens. Alternatively, when an LCD panel is used as the filter, the panel may be programmed to form a pattern so that the incident activating light falls mainly on the thicker center portion of the lens (See Fig. 7, patterns A, B, C, D, F, H, and I). Conversely, for a negative lens, a disk of opaque material may be placed between the lamps 240 and the mold assembly 352 so that the incident activating light falls mainly on the edge portion of the lens. Alternatively, when an LCD panel is used as the filter, the panel may be programmed to form a pattern so that the incident activating light falls mainly on the thicker edge portion of the lens (See Fig. 9, patterns C, F, I, and Fig. 10, patterns A, B, D, E, G, and H).

According to another method, in the case of a negative lens, a sheet material or an LCD panel having a pattern with a variable degree of opacity ranging from opaque at a central portion to transparent at a radial outer portion may be disposed between the lamps 240 and the mold assembly 352. Conversely, for a positive lens, a sheet material or LCD panel having a pattern with a variable degree of opacity ranging from transparent at a

central portion to opaque at a radial outer portion may be disposed between the lamps 240 and the mold assembly 352.

As noted above, the mold assembly 352 may be cooled during curing of the lens forming material as the overall intensity of the incident activating light is increased. Cooling of the mold assembly 352 generally reduces the likelihood of premature release by slowing the reaction and improving adhesion. There may also be improvements in the optical quality, stress characteristics and impact resistance of the lens. Cooling of the mold assembly 352 is preferably accomplished by blowing air across the mold assembly 352. The air preferably has a temperature ranging between 15 and 85°F (about -9.4°C to 29.4°C) to allow for a curing time of between 30 and 10 minutes. The air distribution devices have been found to be particularly advantageous as they may be specifically designed to direct air directly across the surface of the opposed mold members 378. After passing across the surface of the opposed mold members 378, the air emanating from the air distribution devices may be vented out of the system. Alternately the air emanating from the air distribution devices may be recycled back to an air cooler. In another embodiment, the mold assembly 352 may also be cooled by disposing the mold assembly in a liquid cooling bath.

The opposed mold members 378 are preferably thoroughly cleaned between each curing run as any dirt or other impurity on the mold members 378 may cause premature release. The mold members 378 may be cleaned by any conventional means well known to those of ordinary skill in the art such as with a domestic cleaning product, i.e., Mr. Clean™ available from Proctor and Gamble. Those of ordinary skill in the art will recognize, however, that many other techniques may also be used for cleaning the mold members 378.

After curing of the lens in lens curing unit 30, the lens may be de-molded and post-cured in the post-cure unit 40. Post-cure unit 40 is preferably configured to apply

light, heat or a combination of light and heat to the lens. As shown in Fig. 12, post-cure unit 40 may include a light source 414, a lens drawer assembly 416, and a heat source 418. Lens drawer assembly 416 preferably includes a lens holder 420, more preferably at least two lens holders 420. Lens drawer assembly 416 is preferably slidingly mounted on a guide. Preferably, lens drawer assembly 416 is made from a ceramic material. Cured lenses may be placed in lens holders 420 while the lens drawer assembly 416 is in the open position (i.e., when the door extends from the front of post-cure unit 40). After the lenses have been loaded into lens holders 420 the door may be slid into a closed position, with the lenses directly under light source 414 and above heat source 418.

As shown in Fig. 12, it is preferred that the light source 414 includes a plurality of light generating devices or lamps 440. Preferably, lamps 440 may be oriented above each of the lens holders when the lens drawer assembly is closed. The lamps 440, preferably, generate activating light. The lamps 440 may be supported by and electrically connected to suitable fixtures 442. The fixtures may be at least partially reflective and concave in shape to direct light from the lamps 440 toward the lens holders. The lamps may generate either ultraviolet light, actinic light, visible light, and/or infrared light. The choice of lamps is preferably based on the monomers used in the lens forming composition. In one embodiment, the activating light may be generated from a fluorescent lamp. The fluorescent lamp preferably has a strong emission spectra from about 200 nm to about 800 nm, more preferably between about 200 nm to about 400 nm. A fluorescent lamp emitting activating light with the described wavelengths is commercially available from Voltarc as model SNEUV RPR 4190. In another embodiment, the lamp may generate ultraviolet light.

In one embodiment, the activating light source may be turned on and off quickly between exposures. A flasher ballast may be used for this function. The flasher ballast may be positioned beneath the post-cure unit. A flasher ballast may operate in a standby mode wherein a low current is preferably supplied to the lamp filaments to keep the

filaments warm and thereby reduce the strike time of the lamp. Such a ballast is commercially available from Magnatek, Inc of Bridgeport, Connecticut.

Heat source 418 may be configured to heat the interior of the post-cure unit. Preferably, heat source 418 is a resistive heater. Heat source 418 may be made up of one or two resistive heaters. The temperature of heat source 418 may be thermostatically controlled. By heating the interior of the post-cure unit the lenses which are placed in post-cure unit 40 may be heated to complete curing of the lens forming material. Post-cure unit 40 may also include a fan to circulate air within the unit. The circulation of air within the unit may help maintain a relatively uniform temperature within the unit. The fan may also be used to cool the temperature of post-cure unit 40 after completion of the post cure process.

In an embodiment, described as follows, a lens cured by exposure to activating light may be further processed by conductive heating. Such conductive heating tends to enhance the degree of cross-linking in the lens and to increase the tintability of the lens. A lens forming material is preferably placed in mold cavity 900 (illustrated in Fig. 16), which is defined by at least first mold member 902 and second mold member 904. Activating light is directed toward at least one of the mold members, thereby curing the lens forming material to a lens. Heat distributor 910 (shown in Fig. 13) may be adapted to distribute conductive heat from conductive heat source 418 to at least one mold member. Heat distributor 910 is preferably flexible such that at least a portion of it may be shaped to substantially conform to the shape of face 906 or face 907 of first mold member 902 or second mold member 904, respectively. Heat distributor 910 is preferably placed in contact with conductive heat source 418, and mold member 902 is preferably placed on heat distributor 910 such that face 906 of the mold member rests on top of the heat distributor 910. Heat distributor 910 may be coupled to heat source 418. Heat is preferably conductively applied to the heat distributor 910 by the heat source 418. Heat is preferably conducted from the heat distributor 910 through the mold member to a

face of the lens. The heat distributor may be shaped to accommodate face 906 of first mold member 902 or face 907 of second mold member 904 such that the heat is applied to front face 916 or back face 915 of the lens. The temperature of heat source 418 may be thermostatically controlled.

In an embodiment, a resistive heater 418 (shown in Fig. 17) may be used as a heat source to provide conductive heat to the lens. A number of other heat sources may be used. In an embodiment, heat distributor 910 may include countershape 920. Countershape 920 may be placed on top of the hot plate to distribute conductive heat from the hot plate. The countershape is preferably flexible such that at least a portion of it may substantially conform to the shape of an outside face of a mold member. The countershape may be hemispherical and either convex or concave depending upon whether the surface of the mold assembly to be placed upon it is convex or concave. For example, when the concave surface of the back mold is utilized to conduct heat into the lens assembly, a convex countershape is preferably provided to rest the assembly on.

Countershape 920 may include a glass mold, a metal optical lap, a pile of hot salt and/or sand, or any of a number of other devices adapted to conduct heat from heat source 912. It should be understood that Figure 17 includes combinations of a number of embodiments for illustrative purposes. Any number of identical or distinct countershapes may be used in combination on top of a heat source. In an embodiment, a countershape includes a container 922 filled with particles 924. The particles preferably include metal or ceramic material. Countershape 920 may include heat distributor 910. A layer 914 of material may be placed over the countershape 920 or heat distributor 910 to provide slow, smooth, uniform heat conduction into the lens mold assembly. This layer preferably has a relatively low heat conductivity and may be made of rubber, cloth, Nomex™ fabric or any other suitable material that provides slow, smooth, uniform conduction.

In an embodiment, countershape 920 includes layer 914 (e.g., a bag or container)